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7.2.0 V. C. SUMMER INADVERTENT CRITICALITY

Learning Objectives:

1. Briefly discuss the V. C. Summer startup accident.
2. Explain the causes of the accident.
3. Explain the safety implications of the accident.
4. Explain what procedural limitations and administrative controls should have prevented this accident.

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7.2.1 Introduction

V. C. Summer Nuclear Station is a single-unit three-loop Westinghouse plant located in Fairfield County, South Carolina, and operated by South Carolina Electric and Gas Co. The plant began commercial operation on January 1, 1982.

On February 28, 1985, during a startup, the reactor experienced an inadvertent criticality which resulted in a reactor trip. A combination of errors associated with improper operation, inadequate supervision of an operator trainee, and miscalculation of the estimated critical rod position (ECRP) led to the inadvertent criticality. The event could have been easily prevented by better training, supervision and procedural control. The reactor protection system functioned as designed to shut the reactor down before any fuel damage was experienced.

The startup was being conducted by a reactor operator trainee under the supervision of a senior reactor operator (SRO). The ECRP was determined to be 168 steps on control bank D (CBD). The trainee was instructed to withdraw the control banks until the CBD position reached 100 steps. It was thought that this would provide a convenient stopping point with a sufficient margin prior to criticality. Based on calculations after the event, the reactor actually went critical when CBD reached about 40 steps, but no one in the control room realized that the reactor had attained criticality. The trainee continued to add positive reactivity after the reactor was critical with continued rod withdrawal. The SRO blocked the source range reactor trip when the P-6 permissive was received without noticing the rate at which reactor power was increasing. Without the 10^5 cps trip from the source range instruments to stop the power increase, reactor power increased to approximately 6% of rated thermal power with a startup rate of about 16-17 dpm (based on post-accident calculations) before the reactor tripped on high positive flux rate in the power range. Control bank D was at about 76 steps when the trip occurred.

7.2.2 Causes

The reactor startup which took place around 1:30 p.m. on February 28 followed intermittent operation of the unit during the previous month. One of the primary causes of the inadvertent criticality was the incorrect calculation of the ECRP. The calculation for the startup used the power block method of predicting xenon and samarium reactivity worths, which can produce significant errors if the power history is intermittent. The ECRP calculation was made based on a brief period (three hours) of power operation earlier in the day rather than on previous periods of extended operation. Another problem with the calculation involved using middle of life (MOL) rod worth curves rather than beginning of life (BOL) curves, which would have been more appropriate. The licensee's procedure lacked any guidance regarding when the change should have been made to the MOL curves.

The operator performing the startup was a trainee and did not have an NRC license. This is allowable if the trainee has received sufficient training to be able to perform the task normally performed by licensed personnel and is directly supervised by a licensed

operator. The trainee apparently had not received appropriate training because he did not know what the indications of reactor criticality are and he did not know that plant procedures required that the Excore instrumentation should be monitored for indications of criticality any time positive reactivity is being added to the core.

Supervision of the trainee was inadequate, even though several reactor operators and senior reactor operators were in the control room performing other tasks related to the startup. None of the licensed operators recognized criticality and the supervising senior operator even blocked the source range trip as reactor power was increasing into the intermediate range.

7.2.3 Safety Implications

An event more severe than the February 28 inadvertent criticality is analyzed in the V. C. Summer final safety analysis report. The uncontrolled rod cluster control assembly bank withdrawal from a subcritical condition (a Condition II fault of moderate frequency) is analyzed to determine if acceptable fuel limits are maintained during the transient. The event is initiated with a simultaneous withdrawal of two sequential control banks having a maximum combined worth at a maximum speed of 105 pcm/sec (the addition rate was determined to be 10 pcm/sec for the 2/28/85 event). The analysis determined that the power range neutron flux trip (low setpoint) would activate at 35% power (the positive rate trip is not assumed to activate). The peak power attained, limited by the fuel doppler coefficient, is about 600% of rated thermal power (the energy release from an instantaneous power pulse would be very low). No fuel or clad damage results, and the departure from nucleate boiling ratio remains greater than 1.3, according to the analysis. The V. C. Summer inadvertent criticality event was bounded by the accident analysis with considerable margin.

7.2.4 Generic Implications

The inability to accurately predict criticality is a safety concern because technical specifications require that the calculation be performed to verify that the reactor will be critical with rods withdrawn above the rod insertion limit. This is necessary to ensure that there is enough negative reactivity available from the control rods that the reactor can be made subcritical from all operating conditions assuming the worst case conditions.

Even though the inadvertent criticality event was bounded by an analyzed accident, it demonstrated significant weaknesses in the utility's procedures and training for licensed operators. The plant procedure did not provide adequate guidance for the calculation of an ECRP during a period of unstable or unpredictable xenon behavior. Adequate guidance on the correct source of data was not available as demonstrated by the use of the incorrect rod worth curves.

The major contributor to the incorrect ECRP calculation at Summer was the incorrect determination of the reactivity worth of xenon. Summer and other licensees typically used the power block history method to calculate the equivalent power for determining xenon and samarium reactivity worths. With this method the core power level readings

are logged periodically in order to describe the previous core power history. Xenon reactivity is based on the hourly average core power for the 36 hours prior to shutdown. Samarium reactivity is based on the daily average power for the eight days prior to shutdown. In determining the reactivity worth of xenon and samarium, each logged entry has a different coefficient or multiplier associated with it. The entries nearest to the time of shutdown are the most heavily weighted. The power block method of determining the equivalent power level for estimating xenon and samarium reactivities is not very accurate when previous reactor operation is intermittent at widely varying power levels. It was determined that some of the ECRP calculations were in error by more than 50 rod steps when non-equilibrium critical data were used.

Other methods, such as computer programs, are available to determine xenon and samarium worths for use in ECRP calculations. Although potentially more accurate and not subject to calculation errors, problems are still possible with computer programs. Improper data input and software errors during development and updating of the software can introduce problems during use.

Similar instances of incorrect ECRP calculations have occurred on numerous occasions at Westinghouse plants, but proper monitoring of available indications have prevented uncontrolled criticalities and power excursions. Table 7.2-1 is a partial listing of similar events.

7.2.5 Corrective Actions

Following the incident at V. C. Summer, the licensee initiated corrective actions to prevent recurrence. Procedural inadequacies were addressed, and inverse multiplication plots were used for subsequent startups to predict criticality and to verify the accuracy of ECRPs. These actions did not prevent the problem that occurred on 5/11/85. Administrative controls on the conduct of training were improved to ensure proper supervision of on-the-job training.

Following a special inspection by USNRC Region II, enforcement action was taken for the procedural violations and inadequacies. In addition, the licensed operator supervising the evolution received a letter of reprimand.

7.2.6 Summary

The major contributor to the incorrect ECRP calculation at Summer was the incorrect determination of the reactivity worth of xenon. Similar instances of incorrect ECRP calculations have occurred on numerous occasions at Westinghouse plants. The use of inverse multiplication plots to predict criticality and to verify the accuracy of ECRPs and the proper monitoring of available indications help to prevent uncontrolled criticalities and power excursions.

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TABLE 7.2-1 Incorrect ECRPs

<u>Date</u>	<u>Plant</u>	<u>Primary Cause</u>
5/11/85	V.C. Summer	Incorrect ECRP, went critical below the RIL, inverse multiplication plot failed to identify error.
5/17/85	McGuire 2	Incorrect ECRP, went critical below the RIL, error caused by incorrect Xenon worth program.
8/23/84	Turkey Point 3	Incorrect ECRP, went critical 85 steps below ECRP, calculation error.
5/12/84	Turkey Point 3	Incorrect ECRP, went critical 145 steps below ECRP, calculation error.
10/31/84	Turkey Point 4	Unable to achieve criticality, calculation error resulted in improper boron addition to RCS.
5/15/85	Turkey Point 3	Incorrect ECRP, used wrong RCS temperature in calculation (525°F vs. 535°F)

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